THE PROBLEM OF PASSIVE SMOKING

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The United States Surgeon General's Reports have for many years indicted smoking as a cause of diseases of the cardiovascular system, the respiratory system, and of cancers of many organs of the body. Until recently, little concrete evidence indicated that smoking inflicted chronic harm on anyone but the smoker. However, within the past two years evidence has accumulated that breathing tobacco-smoke-polluted indoor air (so-called "passive smoking") may visit the diseases of smoking upon the nonsmoker. Such pollution is substantial: cigarette smokers liberate an estimated 2.25 million metric tons of gaseous and inhalable particulate matter into the indoor environment each year.

This paper reviews the health effects of passive smoking adduced by recent epidemiologic and clinical studies and indicate the substantial support provided by both theory and observation for smoking as a cause of indoor air pollution. The effect of societal decisions involving ventilation of buildings, decisions to smoke, laws governing restrictions on smoking, and the efficacy of various control measures are also discussed.

RECENT STUDIES OF HEALTH EFFECTS OF PASSIVE SMOKING

Cancer. Two recent studies implicate passive smoking as a risk factor in lung cancer, and report statistically significant dose-response relationships. Hirayama,[1] in a 14-year prospective study of 91,540 nonsmoking

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Japanese wives, assessed age-occupation standardized mortality rates for lung cancer relative to their husbands' smoking habits. Wives whose husbands smoked either less than a pack of cigarettes daily or more than a pack daily had respectively 1½ and 2 times the risk of lung cancer of women whose husbands did not smoke, and the risk peaked at 4.6 for wives of agricultural workers aged 40 to 59 who smoked more than a pack daily. Trichopoulos et al.,[2] in a two-year retrospective study of 214 Greek women, found that nonsmoking wives whose husbands smoked either less than a pack per day or more than a pack per day had respectively 2.4 and 3.4 times the risk of lung cancer of the nonsmoking wives of nonsmoking husbands. Hammond and Selikoff[3] reviewed both of these studies, and found no serious flaws.

By contrast, Garfinkel,[32] in an analysis of lung cancer mortality in nonsmokers (where a nonsmoker is defined as one who "never smoked regularly"), concluded that, compared to the nonsmoking wives of nonsmoking husbands, the nonsmoking wives of smoking husbands in the U.S. appeared to have little or no increased risk of lung cancer. However, he further concluded that the variable "husband a smoker" is not an accurate measure of the degree of passive smoking of the wife, thus obscuring any relationship between passive smoking and lung cancer in U.S. wives, and that a very specific epidemiological study which accurately measured exposure was required.

Cardiovascular effects. Aronow[4] studied the effect of passive smoking on exercise-induced angina in 10 patients with angina, in both ventilated and unventilated rooms. He found that passive smoking increased resting heart rate, systolic and diastolic blood pressure, venous carboxyhemoglobin content, and decreased heart rate and systolic blood pressure at angina onset. The magnitude of the effects observed was greater in a poorly ventilated room, and the duration of exercise until the onset of angina decreased by 22% and 38% respectively under conditions of good and poor ventilation. Bocanegra and Espinoza[5] reported two examples of Reynaud's phenomenon in passive smokers. The symptoms were reported in two successive wives of a chainsmoker; the symptoms of both wives disappeared after exposure to the husband's smoke was eliminated.

Respiratory effects. White and Froeb,[6] in a study of the long-term effects of both voluntary and involuntary smoking on 5,210 middle aged persons (of whom 2,208 were excluded because of pre-existing

respiratory disease), divided the subjects into subgroups according to the reported degree of exposure to tobacco smoke. Using two pulmonary function indices (Forced Expiratory Flow [FEF] 25-to-75% and FEF 75-to-85%), they found a dose-response relationship between exposure to smoke and pulmonary function. Nonsmokers in smoke-free working environments had the highest scores, followed by passive smokers, smokers who did not inhale, light smokers, and, finally, heavy smokers. White and Froeb concluded that chronic exposure to tobacco smoke in the work environment harms nonsmokers and significantly reduces small airway function to the level of smokers of one to 10 cigarettes per day.

A study by the French Cooperative Group[7] examined 2,812 nonsmoking wives in relation to the smoking habits of their husbands. 1,863 whose husbands smoked had significantly lower FEF (25–75%), Forced Expiratory Volume (FEV^1) and Forced Vital Capacity (FVC) than wives whose husband did not smoke. The effect showed a dose-response relationship evident only after 15 years of exposure. Tager et al.,[8] in a study of 444 children aged five to nine, found that parental smoking produced a measurable decline in the pulmonary function (FEF 25–75%) of the children. A crude dose-response relationship was observed. Bonham and Wilson,[9] in a study of 1970 data from a national survey of 39,791 children aged from birth to 16 years old, investigated bed-disability days, as reported by adult heads of household, for the two weeks preceding the interview. Data were collected on the number of smokers per household and the number of cigarettes per smoker. Corrected for socioeconomic status and age, children from households either with one or with two or more smokers had respectively 7% and 29% more restricted activity days than children from households with no smoker, and 14% and 29% more bed-disability days respectively because of acute respiratory conditions. Such correlations were not observed for other conditions. For children from families where 45 or more cigarettes were smoked daily, restricted activity days were 46% higher and bed disability days 43% higher than for children in families where no cigarettes were smoked.

Bonham and Wilson[9] found that in 1970 62.2% of children from birth to 16 years old lived in families with one or more smokers and 24.8% lived in families with two or more smokers. (In a crude attempt to ascertain whether these 1970 percentages were still valid, I sampled 56 children representing the combined enrollment of two fourth-grade classes of an elementary school in Prince George's County, Md. 78.6% of the children reported living with one or more smokers, 28.6% reported living with

two or more smokers, and 12.5% of the children reported three or more smokers in their families. Two children reported five smoked at home.)

Symptomatic effects. Barad[10] studied symptomatic effects of passive smoking in a population of more than 10,000 nonsmoking office workers. More than 50% of the nonsmokers reported difficulty working near a smoker, and another 36% said that they were forced to move away from their desks or work stations because of passive smoking. About one nonsmoker in three reported being "bothered" either continuously or very frequently by tobacco smoke at work. In terms of specific symptoms, 48% of the nonsmokers reported conjunctival irritation, 35% nasal irritation, and 30% coughing, sore throat, or sneezing; nearly 25% exacerbation of a preexisting pulmonary condition, 3% aggravation of a cardiovascular disorder, and 10% stated they were "allergic" to tobacco smoke. Nearly one fourth of the nonsmokers very frequently or always reacted to tobacco smoke with frustration, and a similar proportion felt hostile toward smokers or management. 7% of the nonsmokers stated that they had used sick leave during the preceding 12 months because of the tobacco smoke around them at work. In 1978 an estimated 75% of all American employers allowed unrestricted smoking in the workplace.[11]

Indoor air pollution from tobacco smoking. Repace and Lowrey,[12] in a theoretical and experimental investigation of the effect of tobacco smoke on indoor atmospheres, derived a range of airborne exposure for nonsmokers to tobacco tar and nicotine. They concluded that nonsmokers at present inhale from 0 to 14 mg. of highly carcinogenic respirable particulate matter from cigarette smoking daily, with an estimated pulmonary retention half-life of 70 days. They further concluded that the indoor tobacco aerosol is probably the major source of exposure of the population to respirable particles, based upon observed concentrations of this pollutant compared with measurements in tobacco-smoke-free indoor and outdoor environments and in vehicles on busy commuter highways.

TOBACCO SMOKE AND VENTILATION

Repace and Lowrey found that the concentration of tobacco smoke in indoor spaces is directly proportional to smoker density and inversely proportional to the effective ventilation rate. The effective ventilation rate is increased by replacing contaminated indoor air with fresh outside makeup air, by adsorption of tobacco aerosol on surfaces, by high-

efficiency filtration systems, and by a high rate of ventilation air, which improves mixing of fresh air with polluted room air. The effective ventilation rate is decreased by the recirculation of contaminated room air, by low rates of supply air, and by such obstacles to good mixing as few ventilation registers, poor placement of registers, or walls and partitions obstructing air flow. They also found that one brand of cigar tested produced three times the particulate matter and 30 times the carbon monoxide of an average tar cigarette.

Buildings are ventilated to prevent oxygen depletion and the buildup of the products of human metabolism, particularly carbon dioxide. Elevated indoor levels of carbon dioxide produce a feeling of "stuffiness," and may lead to headaches and loss of judgement.[13] Thus, minimum design ventilation rates are usually based upon limitation of the maximum carbon dioxide concentration. This maximum concentration is clearly directly proportional to the number of occupants of the building, and inversely proportional to the building volume and the rate of replacement of polluted indoor air with outdoor air, which has a carbon dioxide concentration of the order of 0.03%. Minimum design ventilation rates are set by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) to limit the buildup of carbon dioxide to 0.25%, and specify no less than 5 cubic feet of make-up air per minute per person (5 cfm./occ.) for this purpose. To control tobacco smoke *odor*, prior to 1975 and subsequent to 1981, ASHRAE recommended higher design rates of ventilation. From 1975 to 1981, to conserve energy, Society standards reduced the maximum recommended ventilation rates to the minimum values. The Society's design ventilation rates for tobacco smoke have been criticized as inadequate to control odor[14] or aerosol concentration[12,14,15] to within the National Ambient Air Quality Standards for a much less noxious aerosol. Moreover, although the Society's design rates form the basis for recommended rates in local building codes, no enforcement mechanism ensures that even the minimum rates for breathing air are observed. For example, the Federal Property Management Regulations, which govern ventilation rates in all federally owned buildings,[16] specify that "outside air intake shall be reduced to the greatest extent possible"; although a 10% recirculation rate is suggested as adequate, federal building inspectors frequently find the "outside air intake in many buildings reduced to zero."[17] The extent to which this is common in nonfederal buildings in unknown, but the

economic factors which face managers of federal buildings are also faced by other building managers. For example, a recent article in *The New York Times* stated that a $56 million control program was being implemented by the City of New York to reduce energy consumption in 274 city-owned buildings. Among the controls to be implemented were measures affecting ventilation.[18]

This trend toward reduced ventilation rates has also been felt in the residential building stock. In the recent past, residential closed window infiltration rates have averaged on the order of one air change per hour (ach.).

Currently, air-exchange rates in new residences appear in the range of 0.5 to 0.7 ach., and some "energy efficient" homes have air exchange rates of the order of 0.3 to 0.5 ach.[19]

This means that average levels of tobacco smoke in both mechanically and naturally ventilating buildings are on the increase, exacerbating the health effects associated with passive smoking. Figure 1 shows the estimated cigarette equivalent inhaled by a nonsmoker versus the effective ventilation rate under conditions of average occupancy in an office.

TOBACCO SMOKE AND REGULATION

An alternative approach to controlling an indoor air pollutant is source reduction. Although Congress has required warnings on cigarette packages and on cigarette advertising, it has been reluctant to provide federal regulatory agencies with the tools to control the product itself. Regulation of tobacco products is specifically proscribed under the Federal Hazardous Substances Act, the Consumer Product Safety Act, the Fair Packaging and Labeling Act, the Controlled Substance Act, and the Toxic Substance Control Act. Under a recent federal court ruling, Congress also did not intend tobacco products to be regulated under the Food, Drug, and Cosmetic Act—even though nontobacco cigarettes can be. Because federal law is preemptive, tobacco products also cannot be controlled by the states. However, restrictions on smoking have been passed in a number of states. In 1979, 38 states introduced 116 bills to limit smoking in public areas. Seven were passed into law in seven states. Of these seven laws, few can be considered comprehensive "clean indoor" laws; most limit smoking in a few areas. Minnesota is presently the only state to restrict smoking in the workplace as well as in restaurants, sports arenas, and other public and commercial buildings.

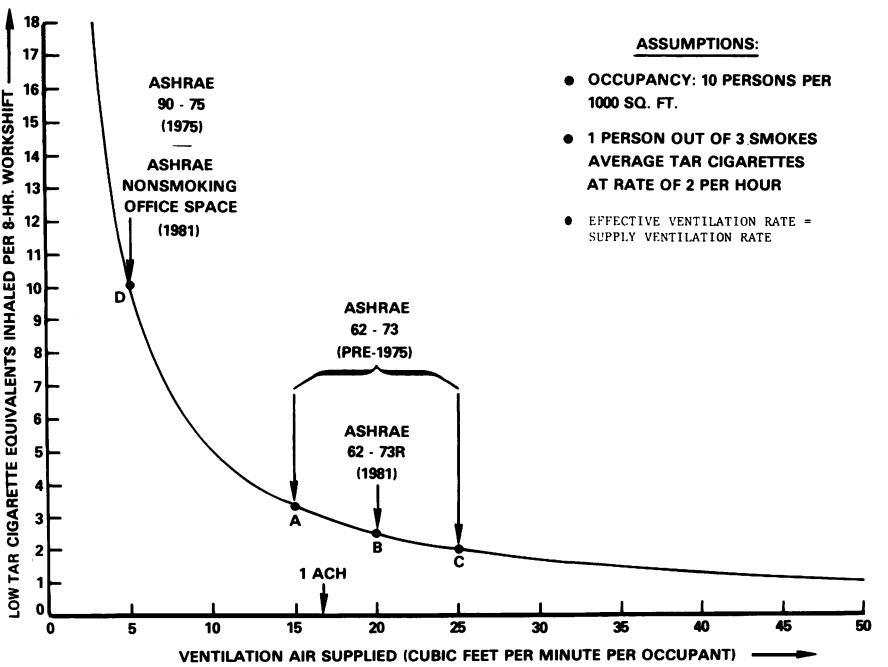

Fig. 1. The curve shows the low-tar (0.55 mg.) "cigarette equivalents" which would be inhaled by a typical nonsmoking office worker breathing indoor air contaminated by tobacco smoke under a continuum of ventilation rates. Points A and C specify the minimum and recommended rates specified by the consensus standard of ASHRAE, under which ventilation rates were set prior to 1975. From 1975 to 1981, to conserve energy in new building design, the recommended rate was reduced to the minimum. In 1981 a revised standard was set specifying vastly different rates of ventilation for buildings where smoking is either permitted (point B) or not permitted (point D). However, no enforcement mechanism exists to prevent smoking in buildings that were not designed for it. To reduce tobacco smoke concentrations in a 10 by 15 foot office occupied by a chainsmoker and a nonsmoker to within limits prescribed by the National Ambient Air Quality Standards for the much less noxious outdoor aerosol, under *ideal* conditions of mixing and with zero recirculation, would require in excess of 30 air changes per hour.[15] Current ASHRAE ventilation rates prescribed for office buildings whose ventilation systems are designed for smoking would expose a nonsmoker to an inhalation of about 2½ cigarettes per workshift.

Minnesota's law guarantees a smoke-free workplace to all nonsmokers requesting it. Enforcement of the law is reported to be "working well."[20] Figure 2 demonstrates the efficacy of nonsmoking sections in large, fairly well-ventilated eating establishments.

Indeed, a 1978 survey of public attitudes toward smoking indicated that a majority of the U.S. public is in favor of separating smokers from nonsmokers in public gathering places, including workplaces.[34] The tobacco industry, however, opposes restrictions on smoking, and its representatives have argued against such ordinances, even at the county

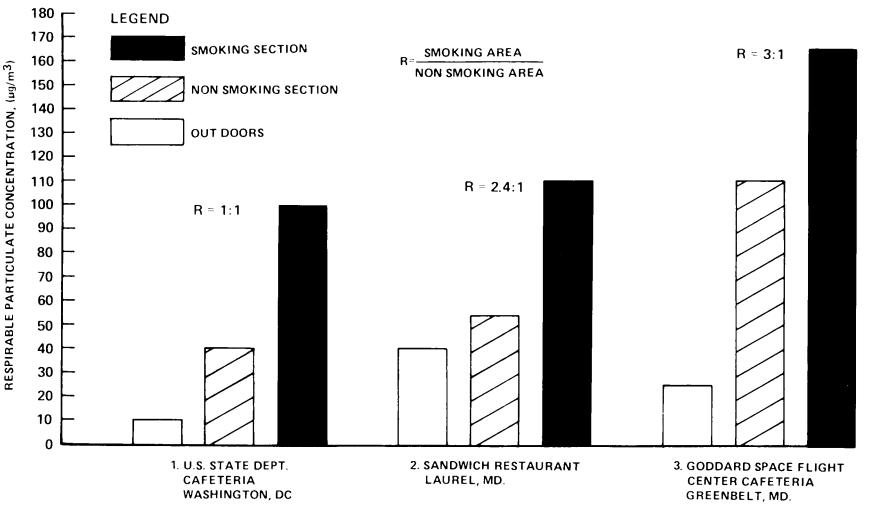

Fig. 2. Nonsmoking sections are effective ways to limit the exposure of nonsmokers to tobacco combustion products. In the State Department Cafeteria and in the Goddard Cafeteria there are no barriers between the smoking and nonsmoking areas, but aisles. In the sandwich restaurant a four-foot-high barrier separates the two sections. The larger the ratio of the smoking area to the nonsmoking area, the less effective the separation. In all cases outdoor air is considerably cleaner than indoor air. The method of measurement is described in Repace and Lowrey.[12] Average sampling times were respectively 32 min., 20 min., and 6 min. for the three establishments.

level. One possible reason for this opposition is economic: The significant decreases in cigarette consumption since 1973 correlate highly with the legislative successes of the nonsmokers rights movement.[35] Although this correlation may not be casual,[35] the finding that nearly 60% of the population believes that smoking is hazardous to the nonsmoker's health has been asserted to be "the most dangerous development to the viability of the tobacco industry that has yet occurred."[34]

Some nonsmokers who have been injured on the job by passive smoking have resorted to litigation to try to establish their right to a smoke-free work environment: these include a group of federal employees,[21] an accountant executive,[22] an engineer,[23] and a computer encoder.[24] Others have successfully collected workmen's compensation for their injuries and include a bank teller,[25] a social services worker,[26] and an airline stewardess.[27]

Federal agencies have smoking policies of varying degrees of rigor. The Department of Health and Human Services provides a smoke-free workplace for its nonsmoking employees on request. Most other agencies do not have individual policies, and rely on general regulations specified by the

General Services Administration. These regulations provide for a smoke-free workplace only by unanimous consent of the employees. OSHA currently has no official policy regarding smoking, and regulation in private workplaces is at the option of the employer. The Civil Aeronautics Board has required since 1971 that all nonsmoking passengers be entitled to a seat in a nonsmoking section on board commercial aircraft. The Board has considered a range of revisions of this rule, ranging from complete revocation of smoking restrictions (favored by the air-lines) to mandatory denial of nonsmoking seating to late-arriving passengers, to a complete ban on smoking on commercial passenger aircraft (favored by organizations such as the American Lung Association).[26] By a narrow margin, it voted to maintain requirements for nonsmoking sections, but waived the right of late-arriving passengers to seating in such sections.

The World Health Organization (WHO) has concluded that tobacco smoking is a major threat to indoor air quality, and has recommended greater efforts to prohibit smoking in public areas.[27] The National Academy of Sciences has reiterated this concern.[33] WHO also recommended that epidemiologic studies of health effects of air pollutants should, where possible, include the effects of passive smoking.

However, much of the work force is in the private sector. What are appropriate roles for corporate preventive health programs? International Business Machines Corp., for example, has guidelines requiring that smokers and nonsmokers be placed in separate offices, or dividing large work spaces into separate sections. Separate sections were provided in the company cafeteria. Martin Marietta Corp. has similar policies. Policies such as these, as Figure 2 shows, effectively reduce exposure. The most effective policies, however, involve actual source reduction. The Dow Chemical Company I. Q. Program provided financial incentives for personnel to quit smoking. Data from the Dow medical department[30] showed that smokers in one of its divisions used nearly 80% more sick leave than nonsmokers, amounting to more than $650,000 in excess wage costs per year. Merle Norman Cosmetics Corp. forbade its 825 employees to smoke. It then returned the savings of $33,000 per year from reduced housekeeping, sick leave, and increased productivity to employees in the form of quarterly cash bonuses.[31] Such efforts deserve widespread support throughout the entire preventive medicine community.

SUMMARY

Within the past two years substantial new evidence concerning the adverse health effects of passive smoking has emerged. This new evidence indicates that well-known health effects of smoking may be suffered by nonsmokers who breathe tobacco-smoke-contaminated air. Concentrations of tobacco smoke indoors are directly proportional to the smoker density and inversely proportional to the effective ventilation rate. Attempts to control smoking by ventilation are futile, requiring ventilation rates far in excess of what is economical, and are contrary to the current trend toward energy conservation in buildings. However, alternative measures which reduce the source have been proved effective.

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